RELATING STRAIN HARDENING TO DISLOCATION DENSITY VIA BROADENING OF BRAGG PEAKS DURING PLASTIC DEFORMATION

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The dislocation density is a feature of the microstructure of a polycrystalline material that is critical to its strength. Models for strain hardening during deformation that is dominated by crystallographic slip rely on a correlation between the square root of the dislocation density and the mechanical strength. Investigations of Bragg peaks in neutron and X ray diffraction experiments have confirmed a square root dependence of the peak width on dislocation density as well. Thus the evolution of dislocation density may be observed indirectly either through increases in strength or by changes in diffraction peak profiles. While the connection between strength and dislocation density is well established, actual measurements of dislocation density are tedious and are seldom made, even though this aspect of the structure is central to the mechanical response. The opportunity to correlate the strengthening attributed to increases in dislocation density to peak broadening offers a more accessible approach. We employ such a correlation to examine the predictions of strain hardening during finite element simulations of plastic deformation. After establishing a proportionality between strength and peak width from simulations of a suite of tension tests, we apply the result to two problems involving inhomogeneous deformation states. The first is an application to bending of a curved beam. Multiscale finite element computations based on crystal plasticity give estimates of the strengthening from plastic deformation throughout the deformation zone. These estimates are compared to those made from peak broadening measurements taken during *in situ* diffraction experiments and the correlation established from the tensile tests. The second application is to the extension of a specimen containing a friction stir welded joint. In this case we relate the evolution the peak width to the inhomogeneous deformation and microhardness. These applications illustrate the methodology to check that the modeled strengthening associated with increasing dislocation density is consistent with the influence that same higher levels of dislocation density have on diffraction profiles.